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LA-UR-87-1955

CONF-870771--1

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LA-UR--87-1955

DE87 011782

TITLE EXTERNAL EXPOSURE ESTIMATES FOR INDIVIDUALS NEAR THE NEVADA TEST SITE

AUTHOR(S) Richard W. Henderson
Richard F. Smale

SUBMITTED TO Evaluation of Environmental Radiation Exposures from Nuclear Testing in Nevada (Symposium) on July 9-10, 1987, Salt Lake City, UT

EXTERNAL EXPOSURE ESTIMATES FOR INDIVIDUALS NEAR THE NEVADA TEST SITE.

R. W. Henderson

R. F. Smale

Los Alamos National Laboratory

Los Alamos, New Mexico 87545

Abstract-- Individuals living near the Nevada Test Site were exposed to both beta and gamma radiations from fission products and activation products resulting from the atmospheric testing of nuclear devices. These exposures were functions of the amount of material deposited, the time of arrival of the debris, and the amount of shielding afforded by structures.

Results are presented for each of nine generic life styles. These are representative of the living patterns of the people residing in the area. For each event at each location for which data exist, a representative of each life style was closely followed for a period of thirty days. The results of these detailed calculations are then extrapolated to the present.

EWB

The model employed is stochastic. The results displayed are the geometric means and standard deviations derived from twenty-five independent determinations of the various quantities shown. For each determination, required parameters are randomly selected from appropriate distributions. The calculations yield estimates for: 1) the whole body and skin dose due to gamma rays from material on the ground, 2) the skin dose due to beta particles from material deposited directly on the skin and, 3) the skin dose due to beta particles from material deposited on the ground.

For the homemaker life style the uterus dose is also calculated as a function of time for nine months. This provides for the estimation of fetal dose as a function of gestation. Organ dose estimates are established from the whole body dose using appropriate conversion factors.

INTRODUCTION

External Dose is here defined to be that dose to the whole body and the various organs resulting from radionuclides external to the body.

The External Dose Assessment Model is designed to follow the activities of an individual through a typical thirty day period following an above ground nuclear event at the Nevada Test Site and use the results to estimate the total dose received. The model is implemented by means of a stochastic code which makes multiple, independent determinations of the various quantities reported.

The stochastic feature of the model is provided by selecting values for the various quantities needed from appropriate distributions during multiple passes through the calculational parts of the code. The various input parameters and tabulated data, representing central values and appropriate measures of dispersion, are either read as data or are assumed. Three separate distributions are used during execution of the code. All exposure rate values are assumed to be distributed log-normally. All values for time, either cloud arrival or changes from one location to another, are assumed to be distributed normally. The distribution of homes for generic life styles are assumed to be uniformly distributed over the 447 examples entered in the data tables. The individual values in the shielding data tables are assumed to be distributed normally.

The model is implemented to yield dose estimates for non-specified individuals using generic inputs. Living pattern information is required for each generic group. These living patterns include the times spent in the various rooms of the house.

Also included is the time spent out of doors, in public buildings, and in an automobile. The time data are specific for the seasons of the year, and day of the week (Sunday, weekday or Saturday). These representative individual values can later be combined with population information to provide estimates of collective doses.

CALCULATIONAL METHODS

Fig. 1 displays a schematic representation of four of the various shielding situations considered.

The model assumes that essentially the entire population may be represented by eight life styles.

The first five life styles are age dependent:

- Newborn - birth to four months
- Infant - four month to one year
- Pre-school - 1 to 6 years
- Elementary student - 6 to 12 years
- Secondary student - 12 to 19 years

The next three life styles are occupation dependent:

- Homemaker - employed full time
- Employed outdoors - farmer, telephone lineman, etc.
- Employed indoors - school teacher, sales clerk, etc.

A ninth life style provides a unique catagory used to demonstrate the effects of shielding on the derived doses for the other life styles:

- Shepherd - full time out of doors

The living patterns representing each of the first eight life styles were derived from the depositions received during the course of the Allen vs. US trial, the responses to the life style survey done in the ten county area near the Nevada Test Site, personal experience and interviews. The Shepherd life style is simply defined as being out of doors all of the time.

Fig. 2 displays the living patterns for the Elementary student life style. Fig. 3 displays the living patterns for the Homemaker life style. In these figures Friday is used to represent all weekdays.

Exposure rate vs. time data are taken from the work of H. Hicks (1981). The exposure rate data points given between one hour and fifty years after detonation were approximated with sums of exponentials (typically eleven) and this function used for subsequent calculations.

It has always been desirable, if not necessary, to express the decay of the fallout radiation field with some sort of mathematical function. The first useful approximations were typically power functions of time. The power function, time to the -1.2, was widely used in the early work involving fission products. This was recognized as an approximation, and various attempts were made to try to improve it. Various schemes were used, including changing the exponent at various points in time. All of these functions could be made to fit the observed data very well over limited time ranges. Thus the observed data were approximated not with a single power function, but with a series of power functions. A different approximation scheme is suggested by the fact that the decay of the fission and activation products is the sum of a large number of exponential functions. The advantages of using sums of exponentials include the ability to approximate the given data to almost any degree of precision desired. The derived sums are all generally within 2% of the data points over the domain of the data. Further the derived function is continuous and integration is srtaightforward. Sums of exponential functions have been derived to represent all of the events as described by Hicks (1981).

These reports also give the radionuclide composition of the fallout as a function of time. These data have been used to provide input parameters for Loevinger's equations. The results of these calculations give beta skin dose rate vs. time curves from material in the air and deposited on the skin during cloud passage and material deposited on the ground. The curves for the ground deposited material are specific for a child or an adult. These four curves (air, skin, child ground and adult ground) for each event have again been fit with sums of exponentials over the period one hour to one month. These functions are then used for integrations during periods of exposure.

The radionuclide data were also used to derive organ dose conversion factors. The data given by Kocher (1980) were used with the Hicks (1981) data to derive the ratio of specific organ dose to whole body dose as a function of time for a typical event. These ratios were essentially constant from one hour to fifty years, and are used in the code as constants.

Fig. 4 shows a stylized representation of an exposure rate curve superimposed on the exposure modifiers for a three day period. An exposure modifier of 1.0 represents a period of time out of doors, a value of 0.5 represents time in a public building, the value below 0.5 represents a value for a bedroom , and the value slightly above 0.5 represents the living areas of a home. The code integrates under the curve between each change in shielding situation and applies the exposure modifier to the integrated exposure.

$$E_i = EM_i \int_{t_i}^{t_{i+1}} ER(t)\, dt$$

$$E_{30\ \mathrm{days}} = \sum_{\mathrm{all}\ i} E_i$$

Where: ER is the Exposure Rate function

EM is the Exposure Modifier for the period

E is the Exposure for the period

The dotted curve in Fig. 4 is the actual function integrated. This detailed calculation is carried out for thirty days. That result is used to extrapolate to the present. This result is the shielded exposure for the individual from the time of cloud arrival until the present. This exposure is converted to whole body dose in Rads (for historical reasons) using a conversion factor derived from Ashton (1979).

Beta skin doses are also calculated during the thirty day period. If the individual is assumed to be out of doors during cloud passage an approximation of the skin contamination is calculated. This is a function of the ground concentration, the fraction of cloud passage out of doors, and a skin contamination factor calculated from data presented by Kochendorfer (1967). These skin contamination factors are calculated as a function of month and time of day, and range from .58 to 4.6. The skin dose rate from this direct contamination is integrated from the end of cloud passage until it is assumed to be washed off by bathing.

During the period of direct exposure to the cloud, the beta particle dose to the skin from immersion is estimated. This is a small component of the total skin dose, since the direct contamination is happening at this same time, but is included for completeness

For each period out of doors, the beta skin dose from material deposited on the ground is calculated. This component represents a larger or smaller fraction of the skin dose, depending on the extent to which the individual was contaminated during cloud passage.

As shown in Figs. 1 and 4, the model requires an exposure modifier for the bedroom and living areas of the home. A data base was generated for these modifiers using representative data for homes extant during the period of atmospheric testing. During a tour of the southeast corner of Nevada and the southwest corner of Utah 447 homes were visually examined and selected for inclusion in the data base, if they appeared to have been there since the fifties. For each selected home the approximate size, roof type, apparent construction, and assumed location of bedrooms were recorded. The location of the home with regard to neighbors was also recorded. Exposure modifiers were calculated for the bedroom and living areas of the homes using methods presented by Spencer (1962). A central value and a measure of it's dispersion were calculated for the living area and bedroom of each of the 447 homes selected.

The basic input data set for the code is an ordered collection of the locations where fallout data were recorded by monitors in the field or for locations included within the bounds of a fallout map. This is the Town Data Base developed by the Desert Research Institute and reported on earlier by Thompson (1987). For each such location the data set includes the name of each event that deposited significant fallout on the location, estimates of the cloud arrival time and the normalized exposure rate at H+12 hours along with expressions of the uncertainties in the estimates. Each record also includes an estimate of the population, by life style, at the time of the event.

For each event at each location the code makes twenty-five estimates of the whole body and beta skin doses for each of the nine life styles. For each estimate the stochastic portion of the code randomly selects a cloud arrival time, a normalized exposure rate and a house from the list of 447. Using these data the code stochastically follows the representative of the life style from change to change for a period of thirty days. During this period estimates of gamma exposure, whole body dose and beta skin dose are made and accumulated. This period accounts for 75% to 90% of the total whole body dose depending on cloud arrival time. It is further assumed to account for 100% of the beta skin dose. The datum for gamma exposure is used to derive an estimate of the whole body dose for the period from the end of the thirty days to the present. During the calculations for the homemaker life style an estimate of the uterine dose is also made. This estimate of uterine dose is used in combination with the exposure decay rate, to produce estimates of the uterine dose for the next eight months.

Each of the twenty-five individual estimates of whole body dose and beta skin dose and the monthly uterine doses are written to a file for subsequent processing. These data are available for statistical analysis as well as being input for population dose calculations. To this end the life style populations have been included with each set of results.

RESULTS AND DISCUSSION

The primary output of the program is a listing of individual dose estimates for all nine life styles for each event at each location where significant fallout was detected. The first tabulation contains the results ordered by location. This includes the population , the name of the event and the results. Estimates are given for the geometric mean of the whole body gamma doses for each of the nine life styles along with the geometric standard deviation of the estimate. This same information is then presented for the beta skin dose. Next the estimates for the uterine doses, as a function of month following the event, are given. These data have been derived for all entries in the Town Data Base. These data will be published later.

Fig. 5 shows the results for the event SIMON, a 43 kt shot detonated on a tower, at Bunkerville, Nevada. This shows the geometric mean and two standard deviations for doses for each of the nine life styles. The figure shows, as expected, that the less shielded life styles are estimated to receive greater whole body doses, but the dose is not a strong function of life style.

Table 1 shows a comparison of the results for Bunkerville Nevada presented by Dunning (1959) and the External Dose Assessment model. The data in this table are all given in rad for consistancy.

The data in Table 2 show a comparison of some of the estimated exposure data presented by Anspaugh (1986) and modified results from the External Dose Assessment model. The output of the code is in rad and was changed to exposure in R. Data for employed indoors and the shepherd life styles is shown to represent the range of the results from the External Dose code. The column headed Beck shows some results of Beck and Krey using modern cesium-137 measurements to estimate the exposure to fallout radiation. The column labeled TMCEFD refers to the results published by the Test Manager's Committee to Establish Fallout Doses. The data Tables 1 and 2 show the general good agreement among these methods of exposure and dose estimation.

The code also produces estimates of population dose. The results from this portion of the code will be reported by Anspaugh.

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FIGURE CAPTIONS

Fig. 1 Shielding Situations

Fig. 2 Living Patterns for the Elementary Student Life style

Fig. 3 Living Patterns for the Homemaker Life style

Fig. 4 Exposure Rate Modified by Shielding Situations

Fig. 5 Whole Body Doses at Bunkerville by Life Style for Event SIMON

Table 1. Comparison of results of Dunning and the External Dose Model at Bunkerville, Nevada

Individual Doses - Rad

Event	Dunning	External Dose Emp Indrs	External Dose Shepherd
ANNIE		.0014	.0053
SIMON	4.0	3.9	5.8
HARRY	.20	.069	.12
CLIMAX		.017	.031
HORNET	.02	.011	.019
ESS	.02	.0033	.0063
ZUCCHINI	.06	.074	.11
PRISCILLA		.0068	.012
SMOKY	.17	.078	.11
Hardtack II	.05		
All Events	4.5	4.2	6.3

Table 2. Comparison of results of Beck and Krey, the TMCEFD, and the External Dose Model

Utah location	Estimated exposure, R			
			External Dose	
	Beck	TMCEFD	Emp indrs	Shepherd
Beaver	≤0.42	0.25	0.21	0.36
Cedar City	0.42	0.64	0.36	0.66
Enterprise	1.22	0.79	0.66	1.5
Hurricane	2.9	3.5	3.6	6.8
Kanab	0.49	1.6	1.3	2.5
Kanarraville	0.49	1.9	1.4	2.4
La Verkin	2.9	3.7	1.8	3.5
Milford	≤0.42	0.10	0.11	0.18
Minersville	0.69	0.20	0.25	0.41
Modena	≤0.42	0.54	0.39	0.55
Mt. Carmel	≤0.42	0.94	0.57	1.1
Panguitch	0.28	0.70	0.48	0.77
Paragona	0.77	0.42	0.26	0.46
Parowan	0.77	0.42	0.29	0.46
St. George	2.6	3.7	3.3	6.7
Santa Clara	1.7	4.3	3.1	5.8
Veyo	4.1	2.8	2.2	4.5
Washington	1.7	3.3	2.5	4.8

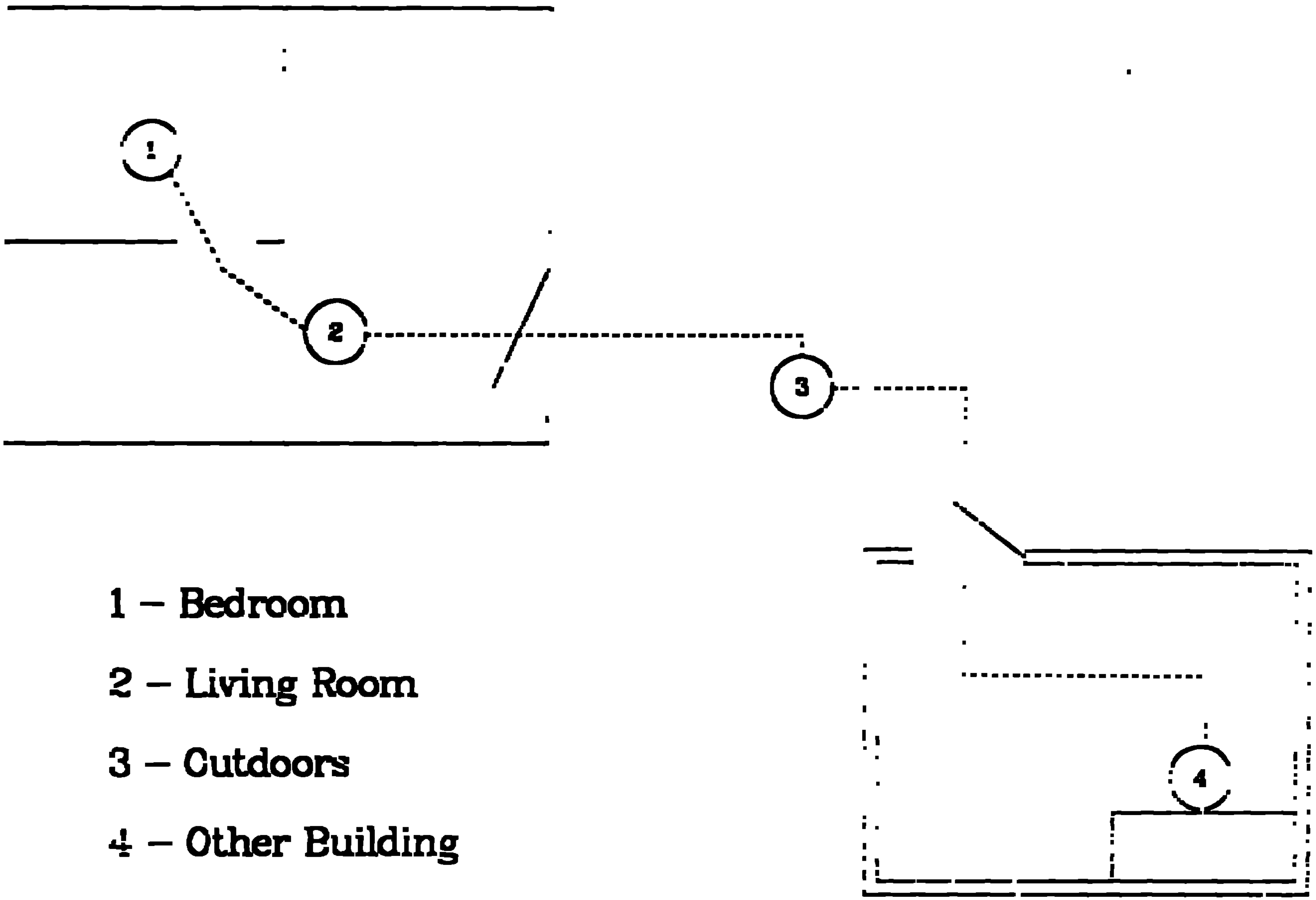

Fig. 1

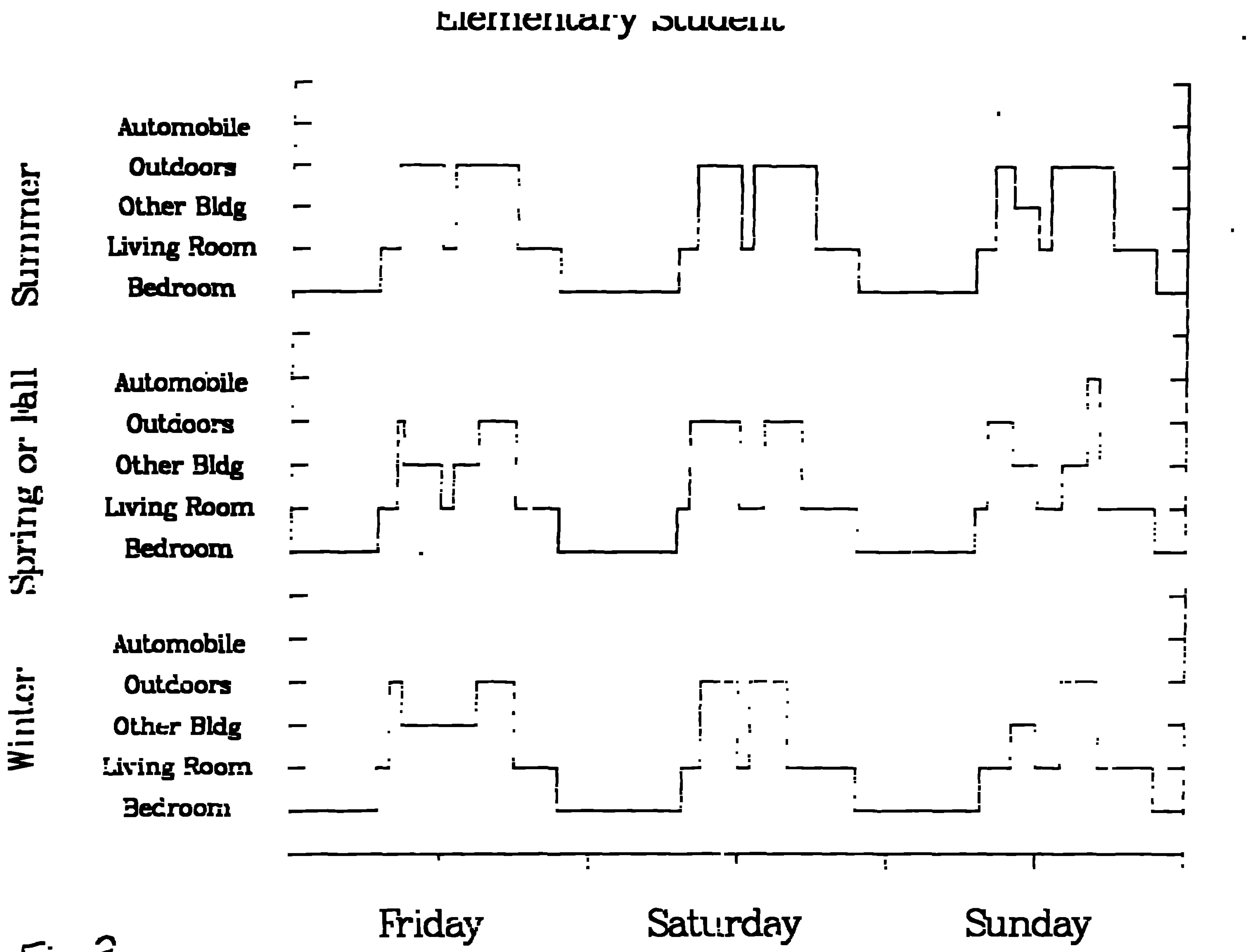
Elementary Student
Summer
Spring or Fall
Winter
Automobile
Outdoors
Other Bldg
Living Room
Bedroom
Friday
Saturday
Sunday

Fig. 2

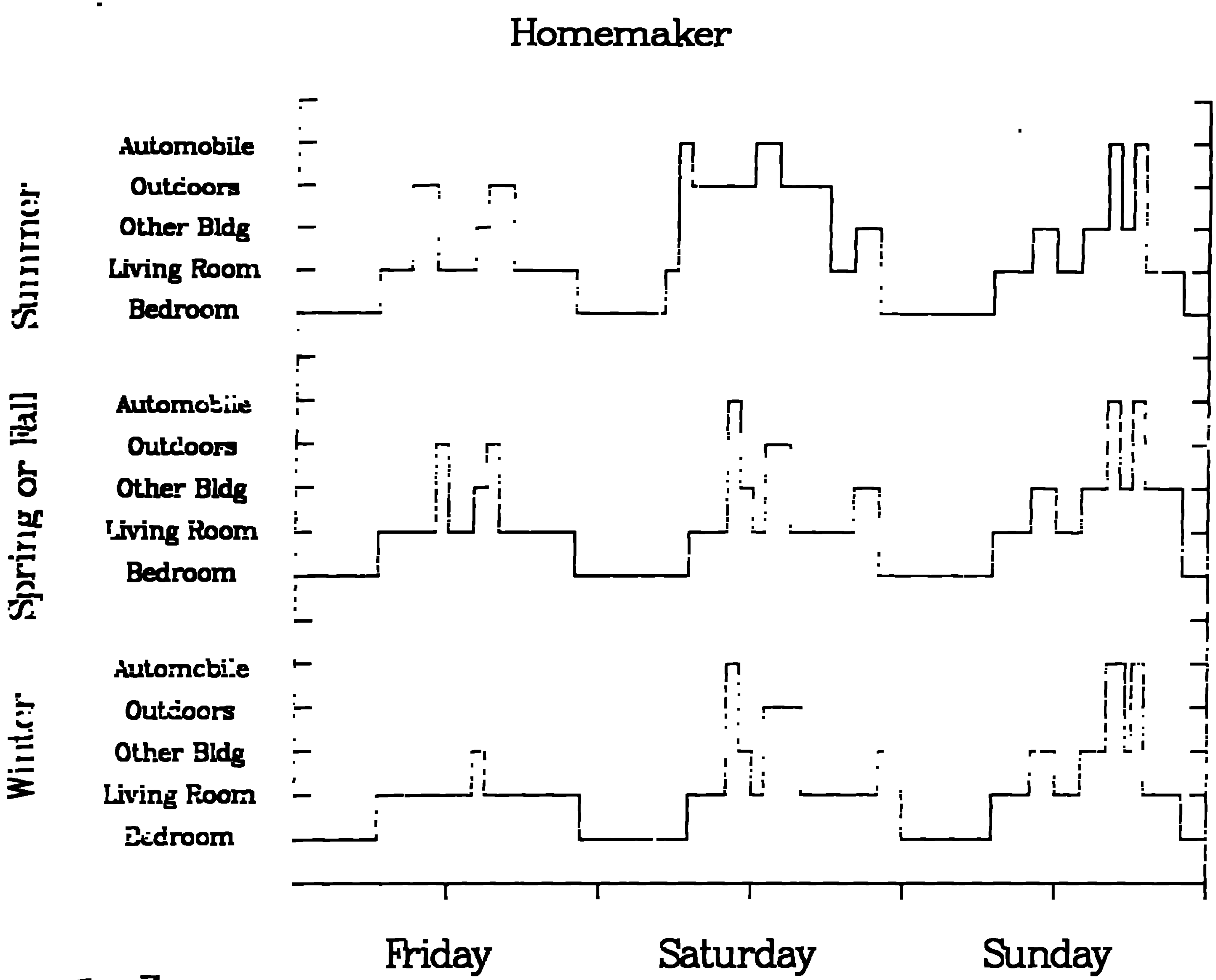
Homemaker
Summer
Spring or Fall
Winter
Automobile
Outdoors
Other Bldg
Living Room
Bedroom
Friday
Saturday
Sunday

Fig. 3

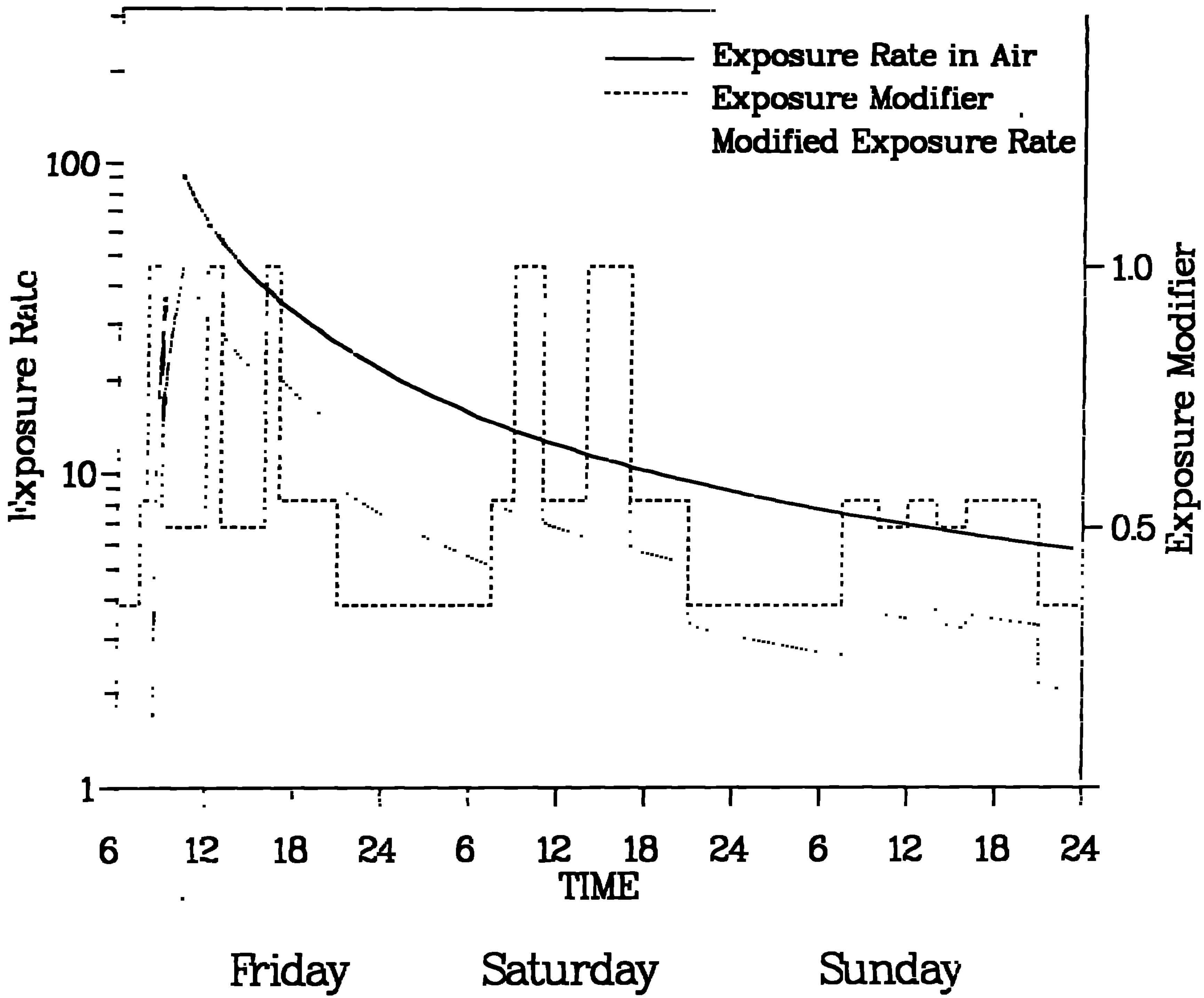
Exposure Rate in Air
Exposure Modifier
Modified Exposure Rate
100
10
1
Exposure Rate
1.0
0.5
Exposure Modifier
6
12
18
24
6
12
18
24
6
12
18
24
TIME
Friday
Saturday
Sunday

Fig. 4

Bunkerville

Whole Body Doses in Gray for Event SIMON
(geometric mean and two standard deviations)

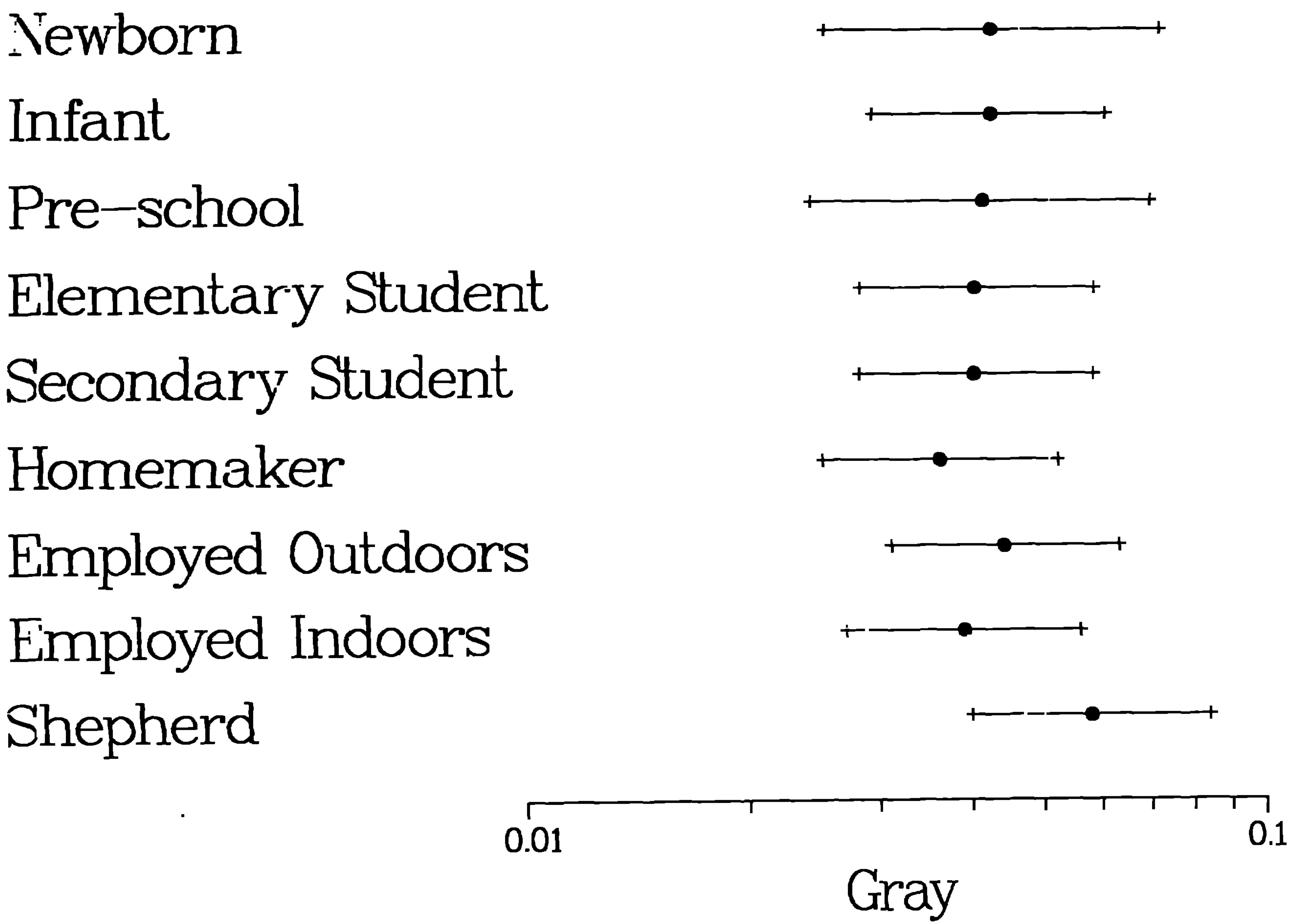

Fig. 5